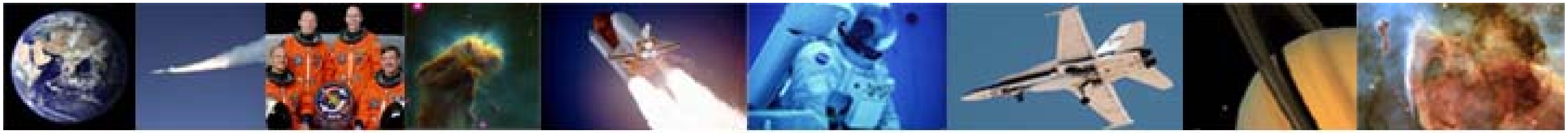

Fire in the Cockpit: The Apollo 1 Tragedy

Leadership ViTS Meeting
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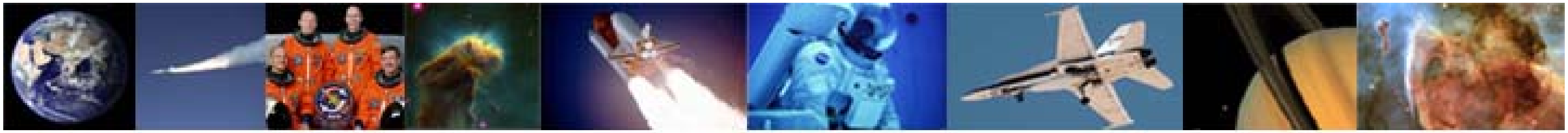


Tragic Loss

- This year marks the 41st anniversary of the Apollo 1 tragedy, when NASA lost three of its finest astronauts to a horrific cockpit fire.
- On January 27th, 1967, the Apollo 1 crew entered the spacecraft to perform a launch countdown rehearsal test. The test commenced with installing the hatch door and purging the cabin with a 100% oxygen atmosphere.

Grissom, White and Chaffee.

- Hours later, a spark from faulty wiring insulation ignited a fire consuming an abundance of flammable materials in the cockpit.
- The fire created an overwhelming pressure against the hatch door, sealing the crew inside.
- Rescue teams, fighting the fire and smoke escaping the cockpit, were able to remove the hatch door within 6 minutes. But by then, the entire crew had been lost.

Pad 34 – site of the Apollo 1 fire.

Costly Design Choices

- Teflon was specifically chosen for the wire coating due to its excellent insulation, chemical inertness and fire resistance. However, Teflon is soft and therefore susceptible to creep, or cold-flow deformation, and abrasion. The Teflon coating had worn away during operations, exposing the electrical wiring.

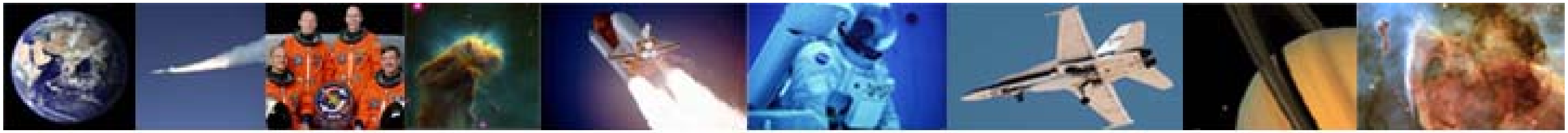
- The single gas design (oxygen) was selected over a two gas design (oxygen and nitrogen) for mass considerations, complexity and reliability concerns, and crew vulnerability to the “bends” (nitrogen bubbling in the body tissue during a rapid decompression event). Over 1000 hours of flight time without incident had been previously logged with a 100% oxygen atmosphere despite the threat of fire and physiological detriment.

- Despite the intent to limit flammable material in the 100% oxygen atmosphere, there existed an irreducible amount, such as pressure suits, at the time of the fire.

- After a premature release error on an outward opening hatch door in a previous design, the hatch design was switched to an inward opening door. This new design required the removal of six bolts to open.

Wires where the fire is believed to have started.

National Aeronautics and Space Administration

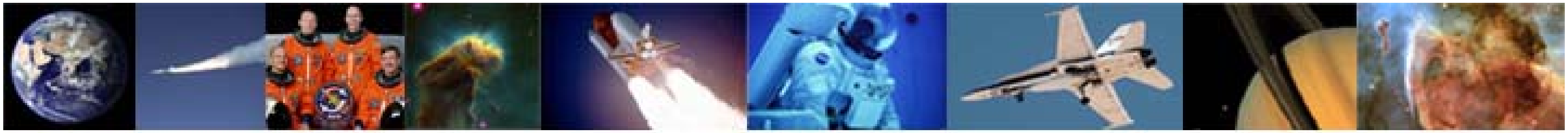


Proximate Cause

- A spark caused by an electrical short in a 100% oxygen atmosphere set fire to an abundance of flammable material.

Root Causes/Underlying Issues

- Vulnerable design and material choices for wiring, atmosphere, cabin materials, and hatch door.
  - Teflon-coated wiring
  - Single gas vs. two gas
  - Flammable cabin materials
  - Inward opening hatch door
- Poor quality control and workmanship.
  - KSC Quality Inspector cited multiple deficiencies concerning equipment, parts, procedures, workmanship and contamination.
- Inadequate provision for emergency response, rescue and medical assistance.
  - There were no contingency preparations or procedures for internal Command Module fires.
  - Emergency equipment was not designed for the high levels of smoke and fire experienced.
  - Fire, rescue and medical teams were not initially in attendance when the fire started.
- Budget and schedule pressures resulted in the over-prioritization of speed to completion.
  - Cost overruns and schedule delays were acknowledged as contributing factors to the design, manufacturing, and quality control process issues.



Lessons Learned for NASA

- Past successes do not obviate the need to continually reassess the rationale for accepted risks.

  NASA had "successfully" logged over 1000 hours of flight time under the same conditions before the Apollo 1 fire.

- Expertise in materials properties throughout a defined and understood range of operating conditions is crucial.

  Teflon may have been the correct choice for insulation and fire resistance, but it was the wrong choice for resistance to deformation and damage, leading to a string of cascading failure modes and effects.

- Use a system safety perspective and integrate hazard analyses to isolate failures and prevent them from cascading into system failures.

  The faults in using mechanically soft insulation to protect against an electrical spark in a 100% oxygen atmosphere in a sealed room full of flammable material with an inward opening door can only be seen through a systems mindset.

- Don't let today's solution become tomorrow's problem.

  The inward hatch design was a direct response to a failure in the outward design. Cold-flow of Teflon led to the use of Kapton, which later was a source of a number of failures itself. Focus on proactive instead of reactive design.